Incorporating plant plasticity in agroforestry simulation models

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Unité mixte de recherche

Fonctionnement et conduite des systèmes de culture tropicaux et méditeranéens

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Incorporating plant plasticity in agroforestry simulation models

I. **Evidence of plasticity in Poplar / Walnut – wheat agroforest systems**

II. **Simulating crown plasticity**

III. **Simulating root plasticity**

IV. **conclusion**

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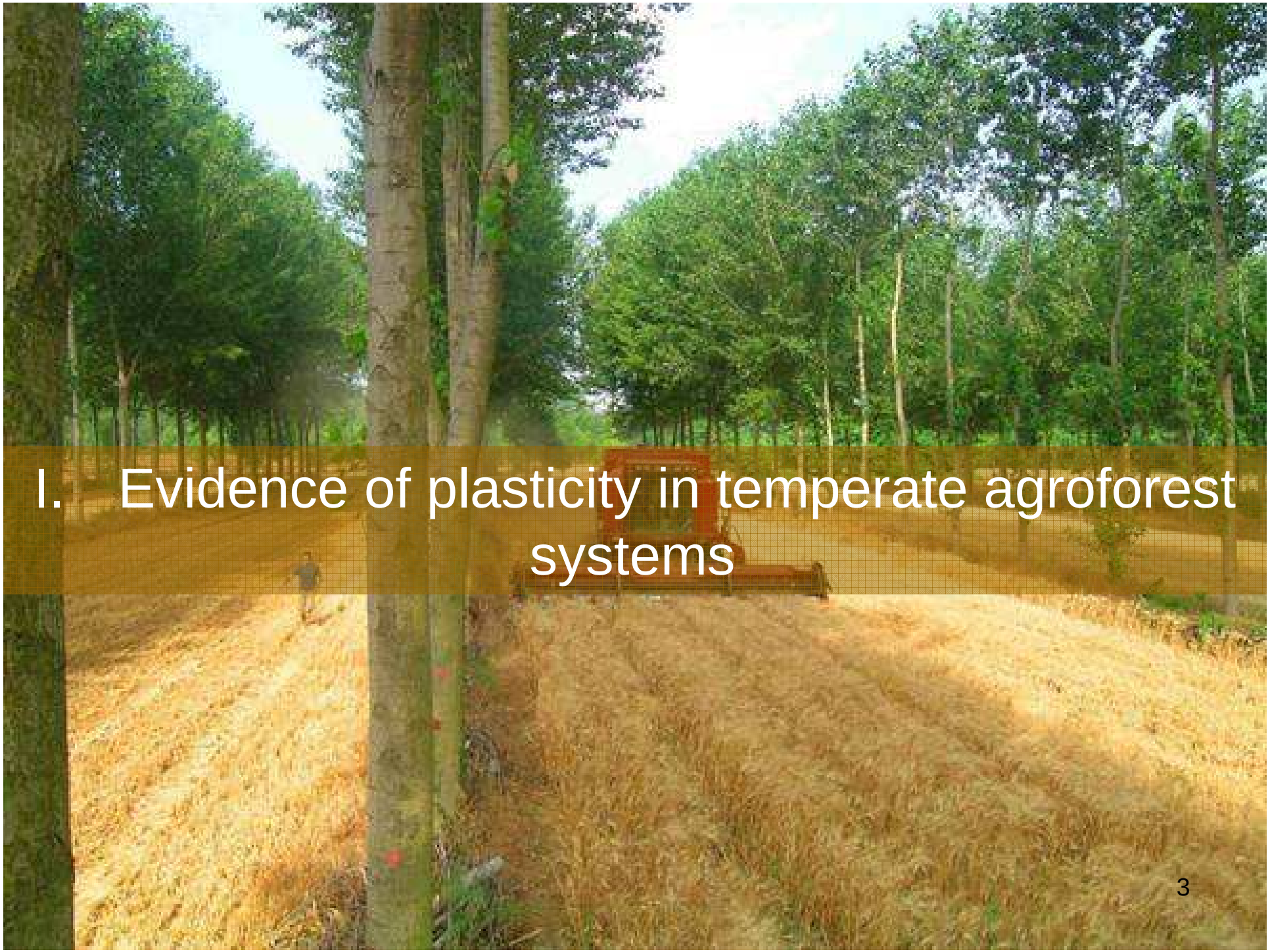
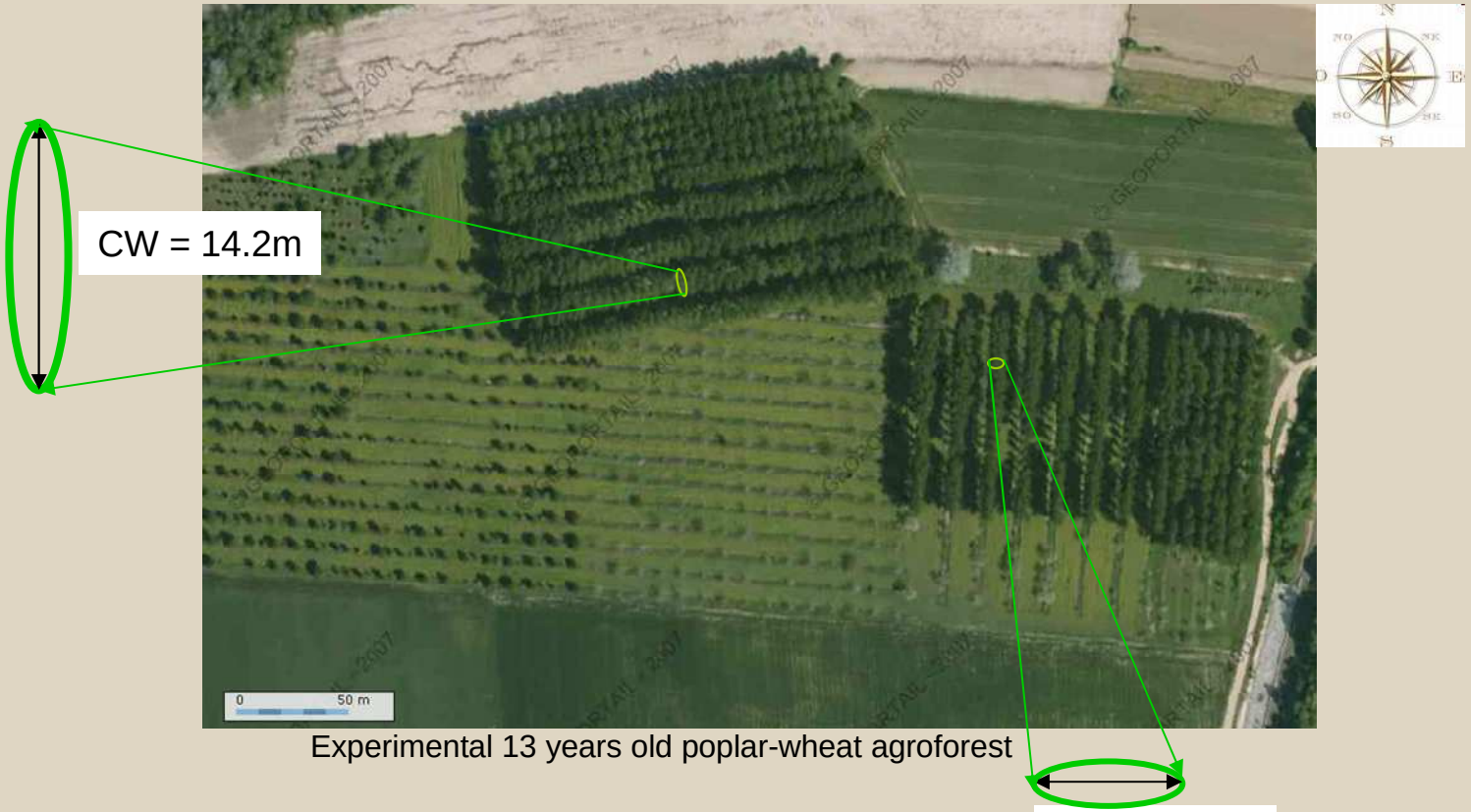


I. Evidence of plasticity in temperate agroforest systems

I. Evidence of plasticity in Poplar – wheat agroforest systems



Experimental 13 years old poplar-wheat agroforest

CW = Crown Width

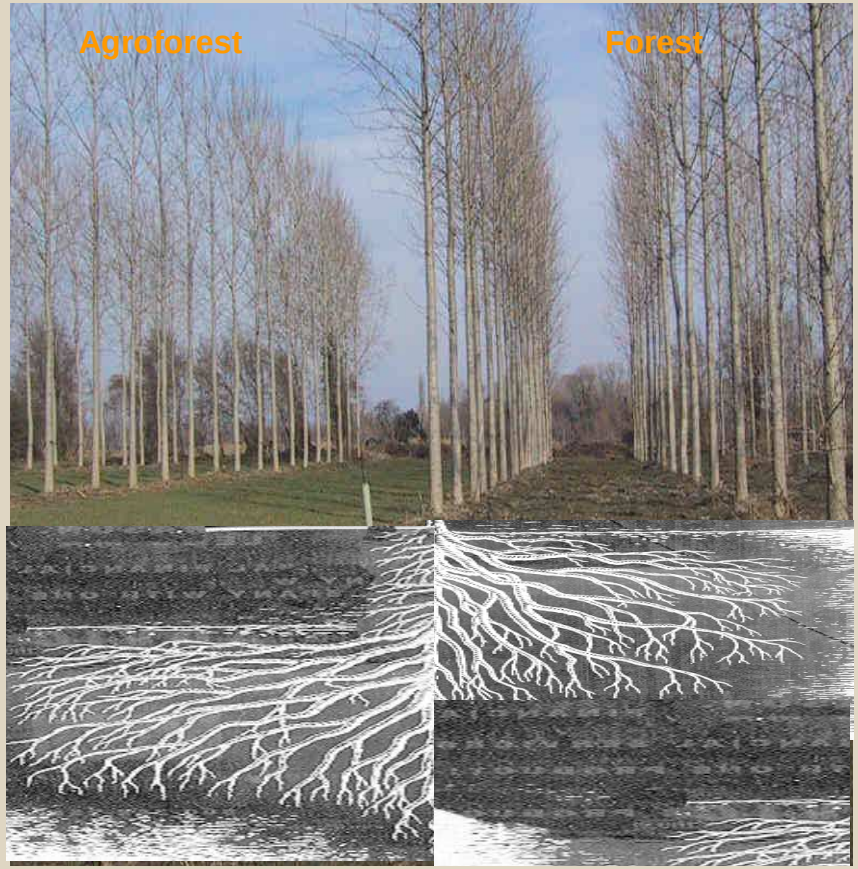
Crown plasticity

- A higher stretching in east-ouest than in north – south in orientation

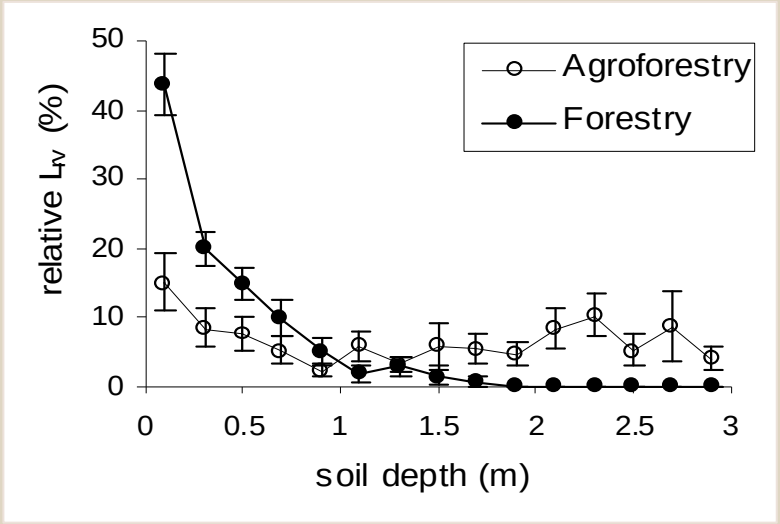
consequences:

- productivity of the system because of light availability

I. Evidence of plasticity in poplar/walnut – wheat agroforest systems



Fine root distribution of Hybrid walnut



Roots plasticity

- fine root distribution is modified by association with a winter crop

Interest in agroforestry

- spatial complementarity for water ressource

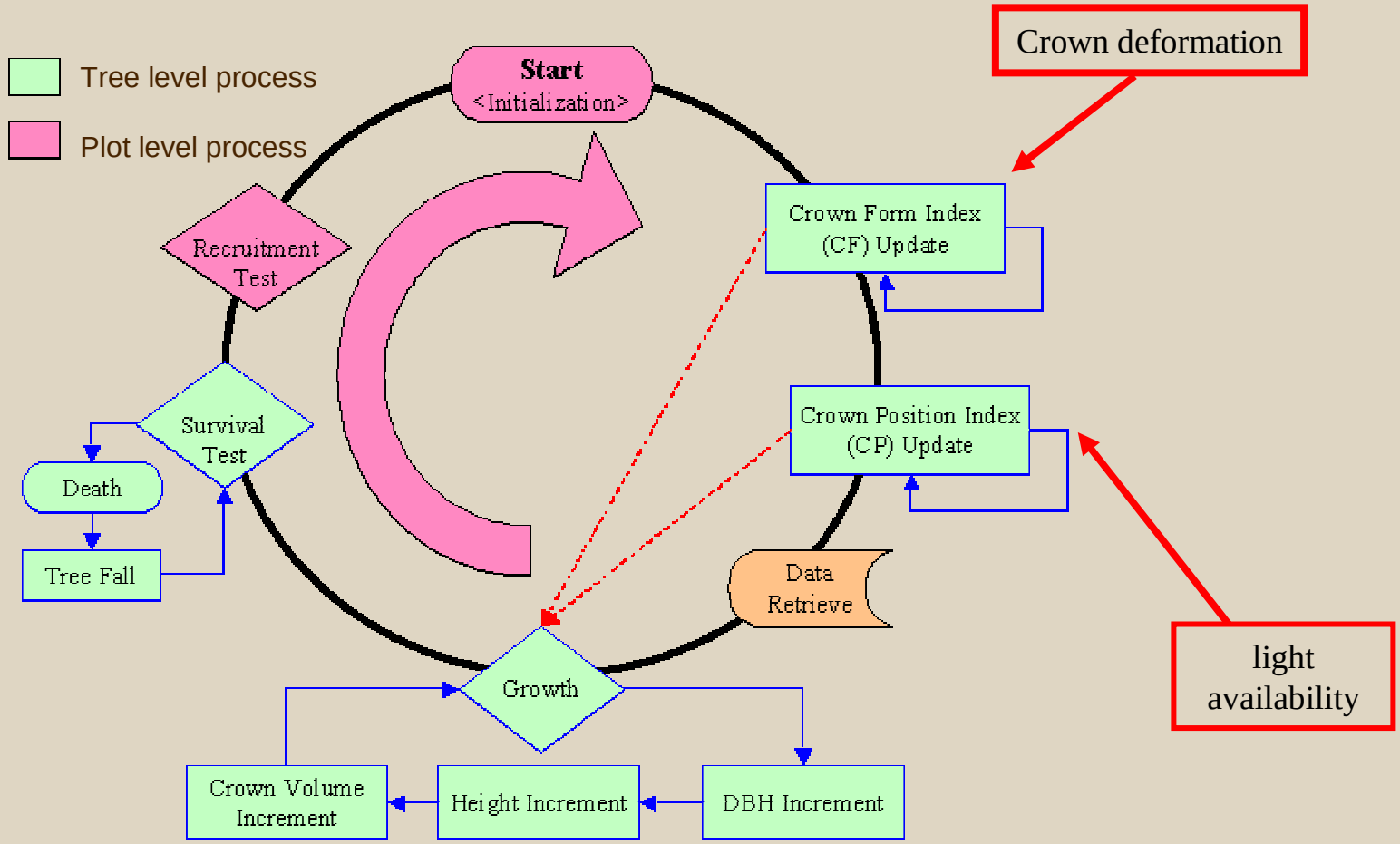
Objectives

- Reconstruction by modelling crown / root plasticity
- Exploration of the sensibility of the systems to the plasticity of trees by comparing simulations with or without plasticity

II. Simulating crown plasticity

II. 1 The model: STReTCH (Vincent & Harja, 2007)

Shape transformation response of trees in crowded habitats



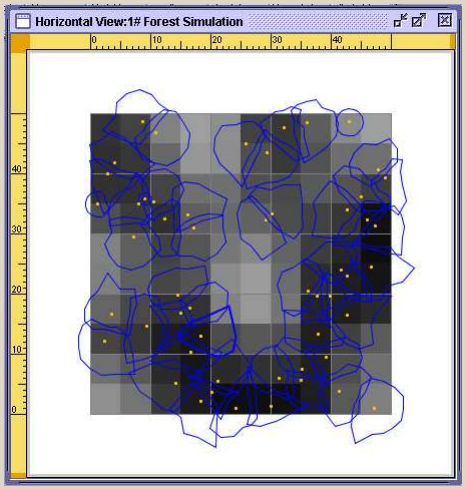
The yearly simulation loop

A combination of 5 modules : growth, mortality, regeneration

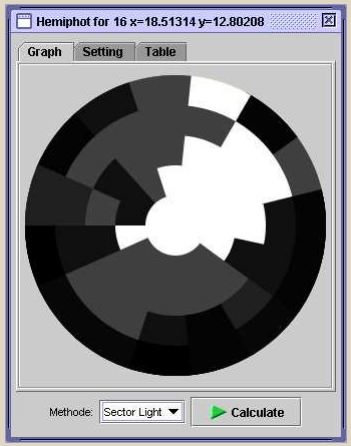
light availabity, crown deformation.

II. 1 The model: STReTCH (Vincent & Harja, 2007)

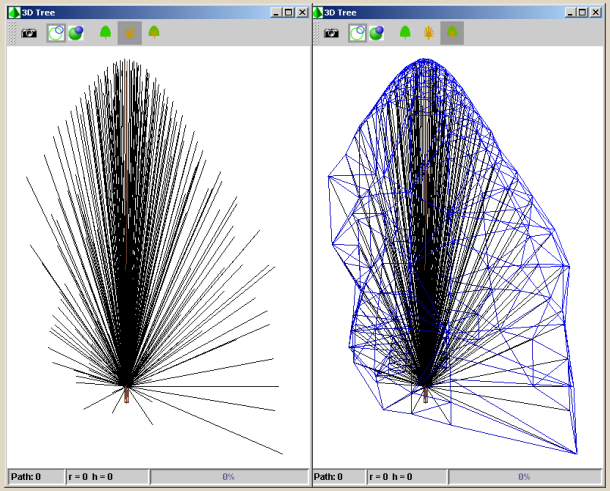
Shape transformation response of trees in crowded habitats



Plot radiative conditions



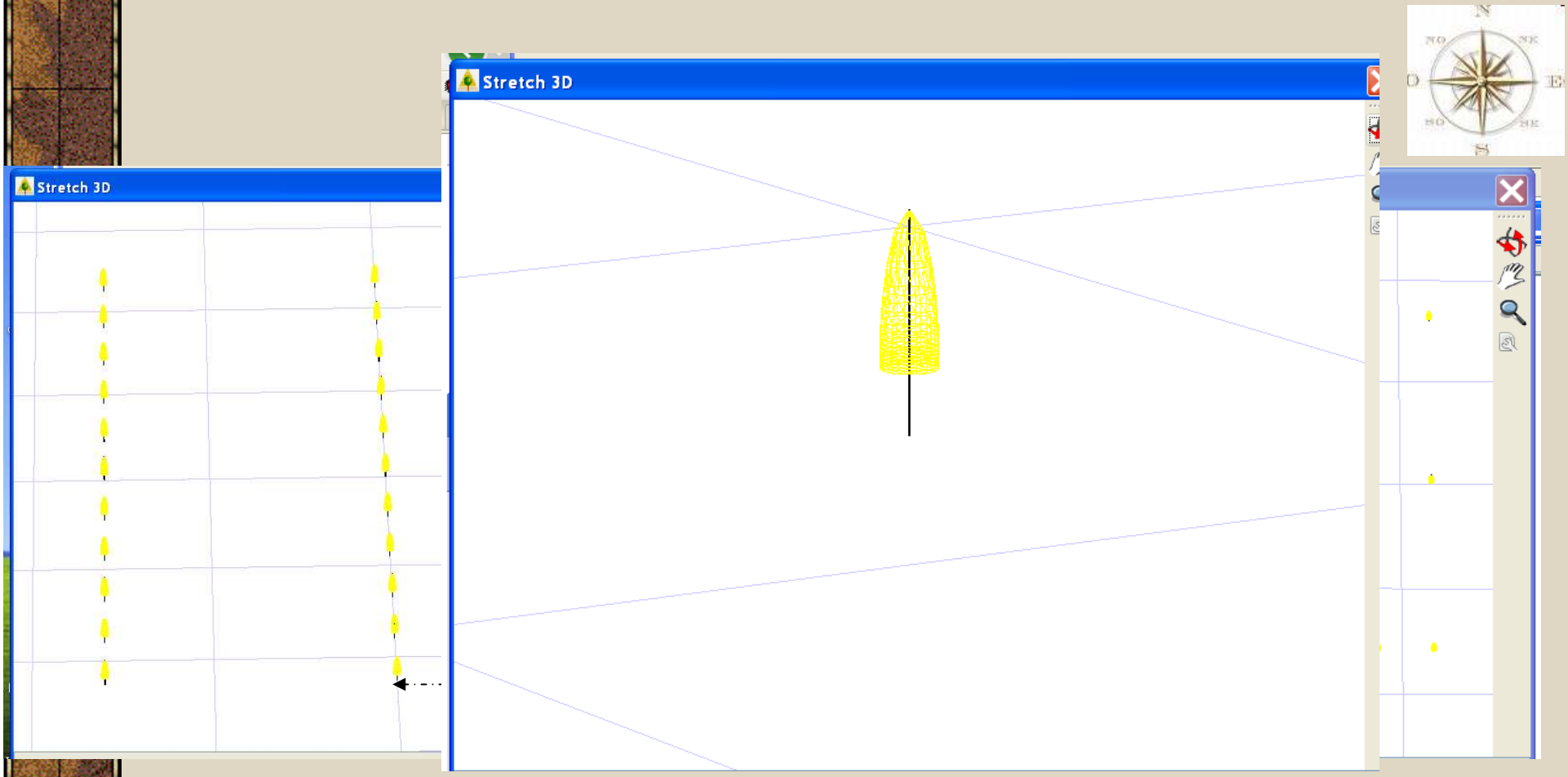
Tree light availability



Growth of virtual branches

- Depends on the stem growth
- Depends on individual light availability
- Virtual vectors of branches

II. 2 Simulation



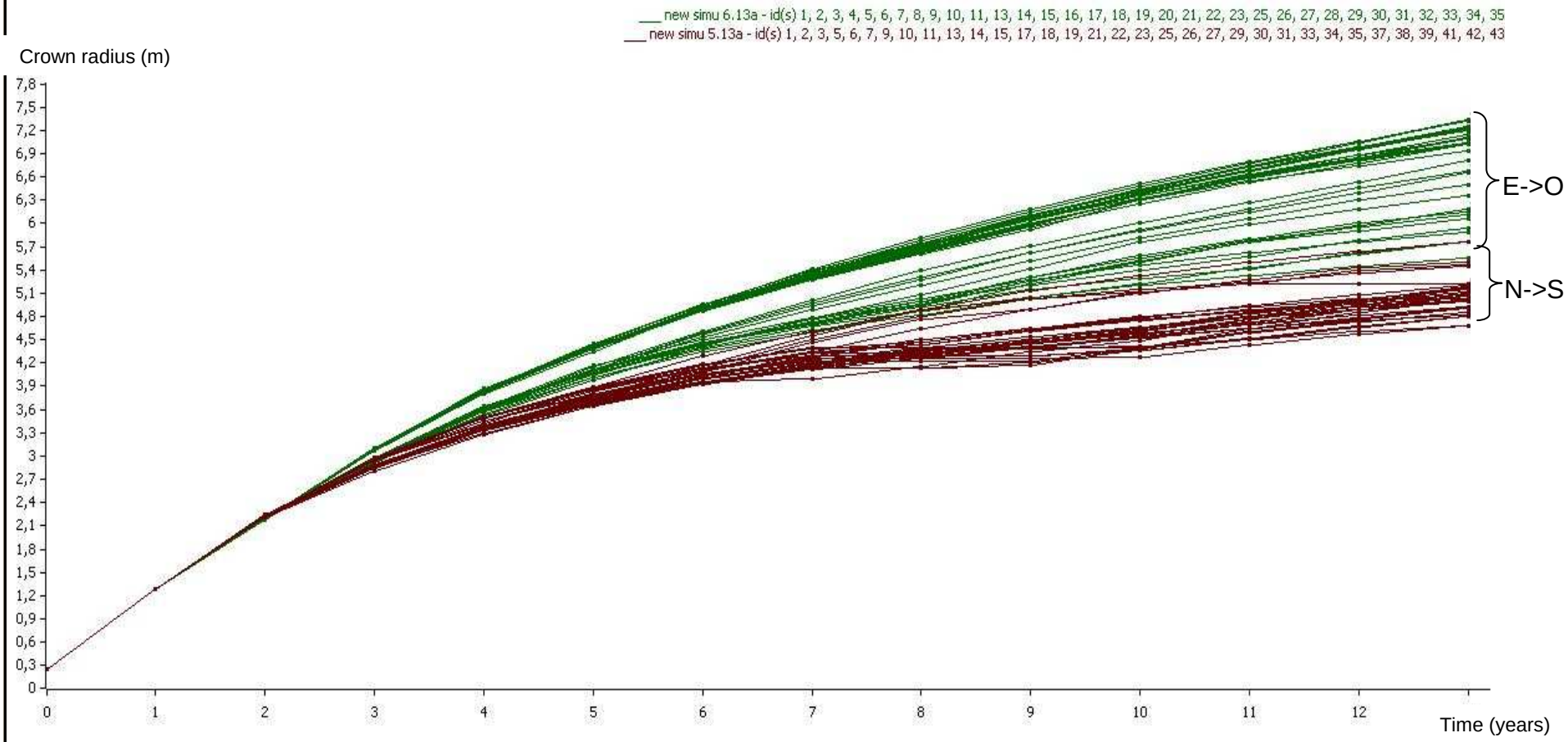
Stand initial conditions

Plasticity parameters (Vincent & Harja, 2007)

Flexibility: range of possible deformation of the trees

Sensitivity: reactivity to a light gradient

II. 3 Results



Orientation N->S Crown radius / time Orientation E->O

CWsimulated = 10.1m

CWreal = 11.2m

CWsimulated = 13.4m

CWreal = 14.2m

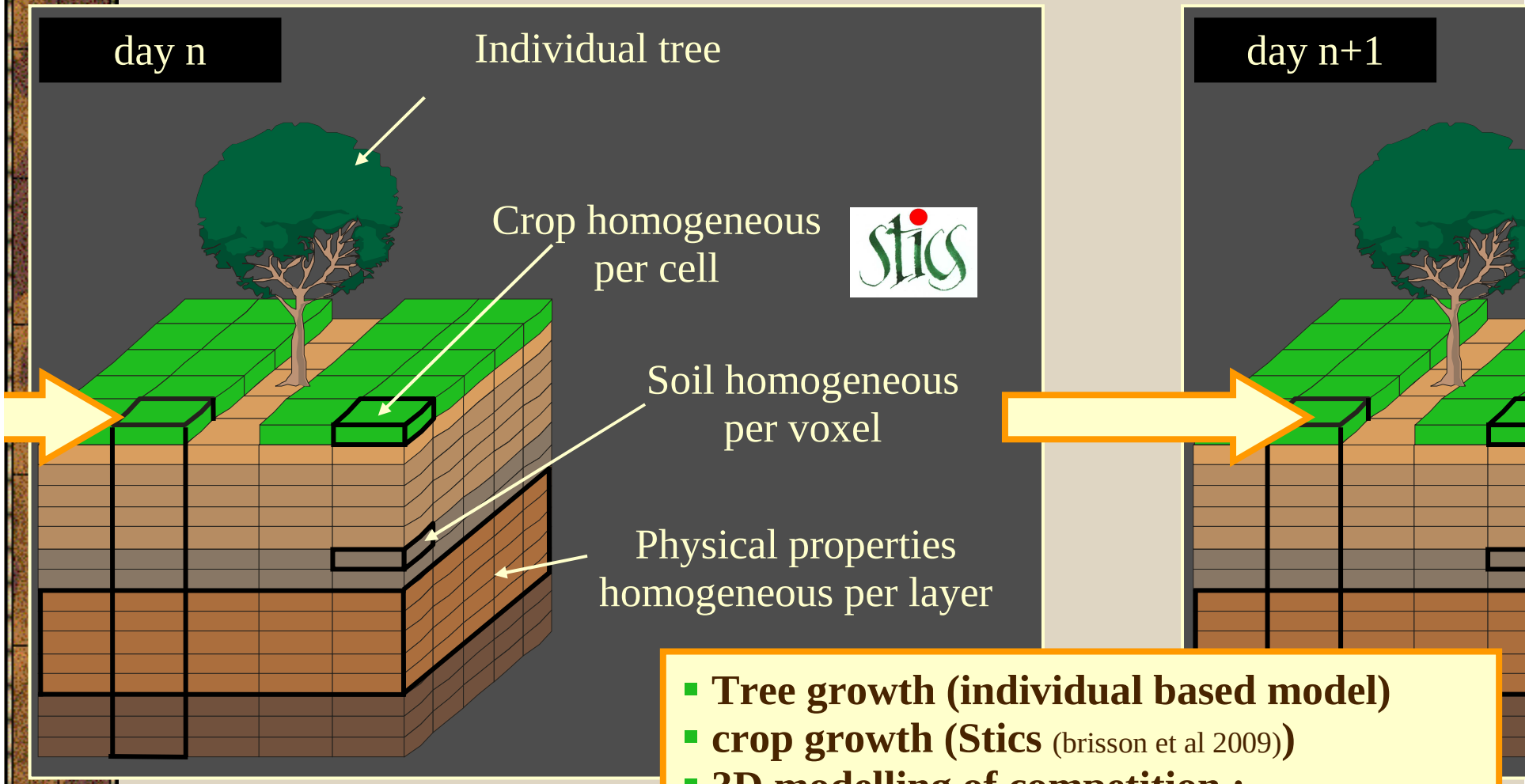
Reconstruction of the differential deformations between the orientations

A high plasticity of poplar crown

- Crown flexibility = 0.8 (range [0-1])
- Crown sensitivity =1.5 (range [0-2])

III. Simulating roots plasticity

III. 1 The model: Hi-sAFe, an overview



- **Tree growth (individual based model)**
- **crop growth (Stics** (brisson et al 2009)**)**
- **3D modelling of competition :**
  - **light (ray-tracing)**
  - **water (matrix flux potential)**
  - **(and soon : Nitrogen)**

III. 1 The model: Modelling root plasticity with a cellular automata

Allocation to voxel *ijk* :

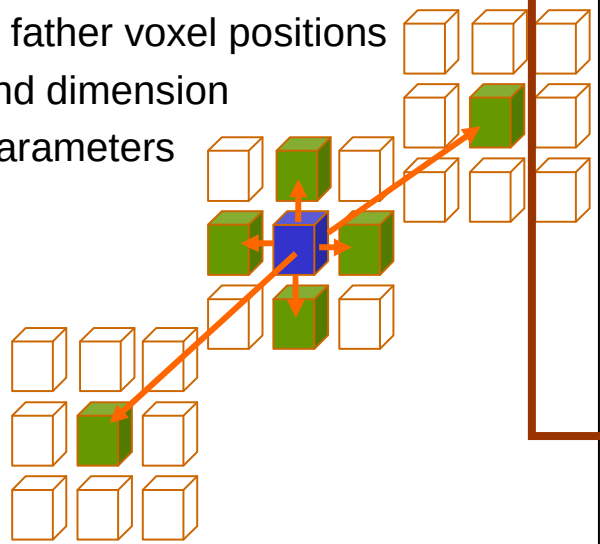
$$p_{ijk} = \frac{\varepsilon_{ijk}^{\alpha} c_{ijk}^{-\beta}}{\sum_{ijk} \varepsilon_{ijk}^{\alpha} c_{ijk}^{-\beta}}$$

p_{ijk}	allocated proportion
ε_{ijk}	water uptake efficiency ($L.m^{-1}$)
c_{ijk}	fine root cost ($Kg.m^{-1}$)
α	opportunism coefficient
β	economic coefficient

Root plasticity

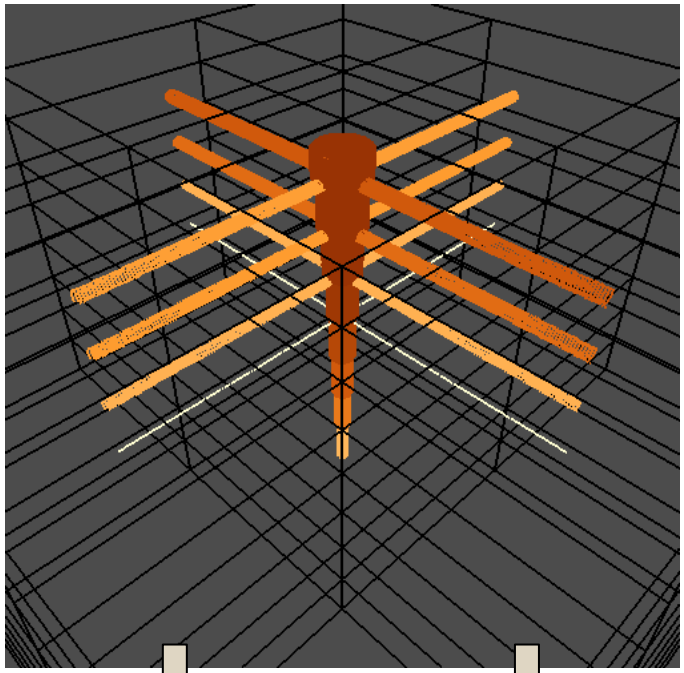
Neighbours colonisation :

- triggered by thresholds on fine roots investment in the voxel
- thresholds depends on :
  - neighbour and father voxel positions
  - voxel shape and dimension
  - architectural parameters



Coarse root system :

- topology : colonisation historic
- sections : Pipe-stem model



Constraints on fine root growth

FR/CR allocation

III. 1 The model: Modeling plasticity in above/below-ground allocation

- Definition of a target shoot/root ratio : $R^* = \frac{C_{\text{leaf}}}{C_{\text{leaf}} + C_{\text{fineroots}}}$
- Daily allocation tends to reach R*
- Allocation toward woody compartments depends on :
  - allometric relationships between stem, branches and foliage
  - functional constraints between coarse roots and fine roots

$$R^*_{t+1} = R^*_t - \delta W^{\phi}_{\text{stress}}$$

- R* decreases when water stress occurs :

$$R^*_{t+1} = R^*_t + \delta$$

- R* upper drifts in absence of water stress :

δ	maximal daily variation of R^*
$W_{\text{stress},t+1}$	water stress on day $t+1$
ϕ	sensitivity to water stress

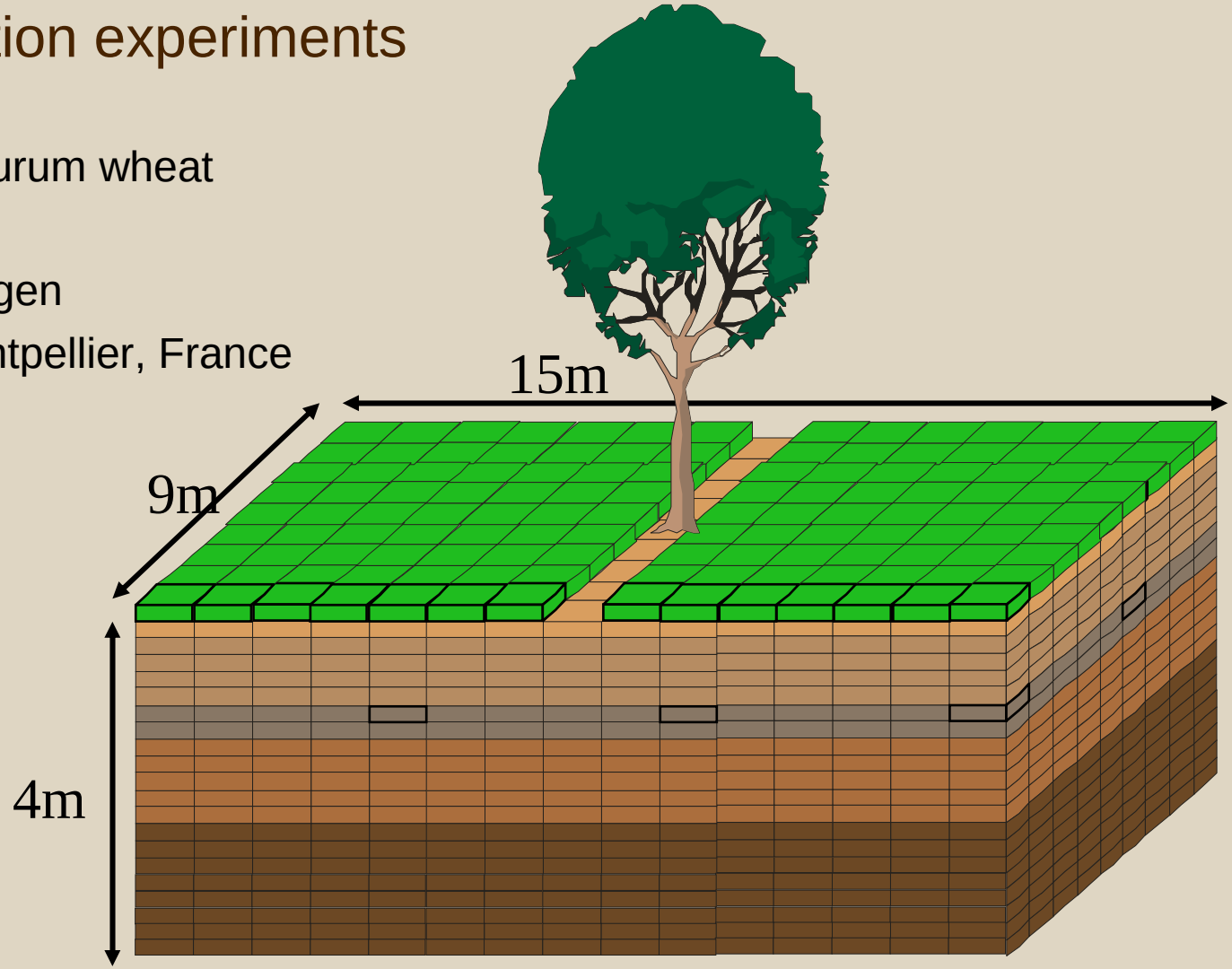
III. 2 Simulation experiments

Hybrid walnut / durum wheat

No water table

Non limitant nitrogen

Climate from Montpellier, France



Root plasticity :

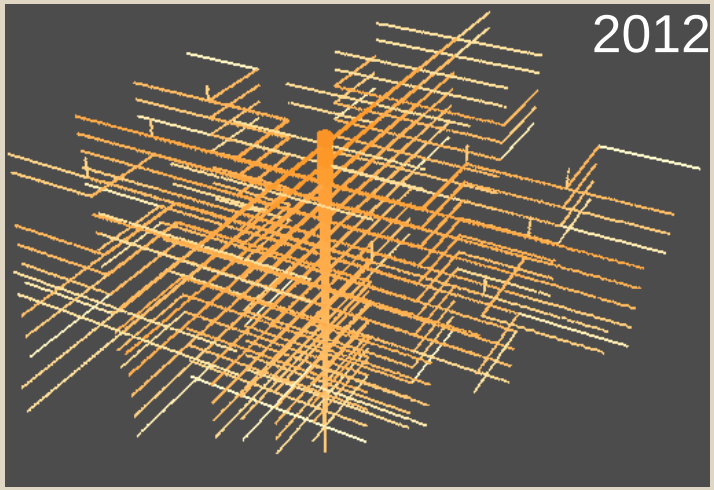
« blind » root system : $\alpha = 0$, $\beta = 1$ opportunistic root system : $\alpha = 1$, $\beta = 1$

Above/below ground allocation :

Rigid tree : $\delta = 0$, $R^*_0 = 0.5$ plastic tree : $\delta = 0.0015$, $\phi = 0.5$, $R^*_0 = 0.5$

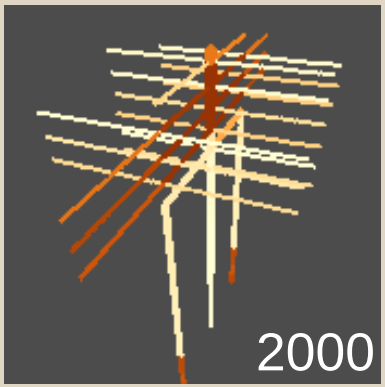
III. 3 Results: Opportunistic root system : effect on rooting pattern

« blind » root system : a half-sphere like growth

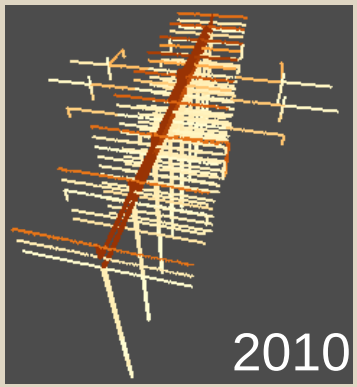


Opportunistic root system : a growth…

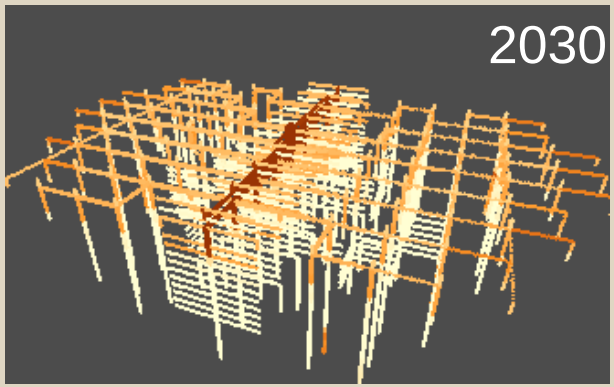
…first in depth…



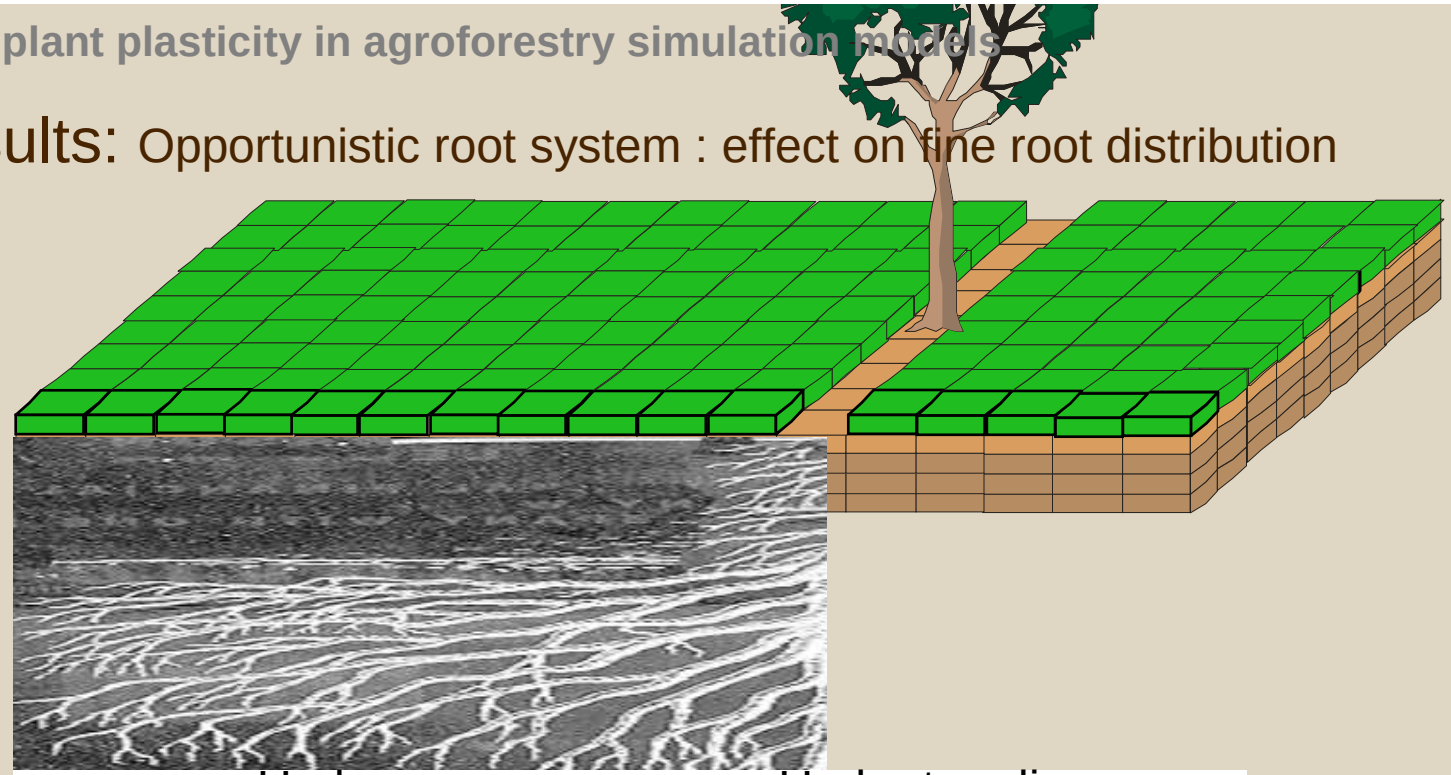
… then along tree line…

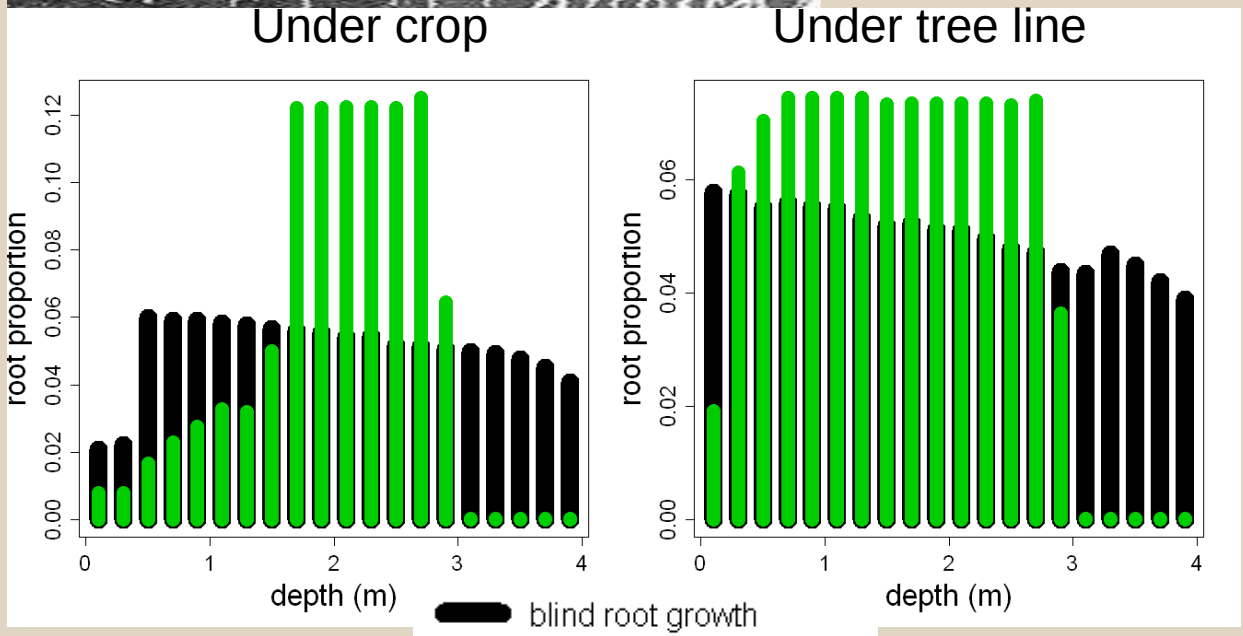


… and finally under the crop

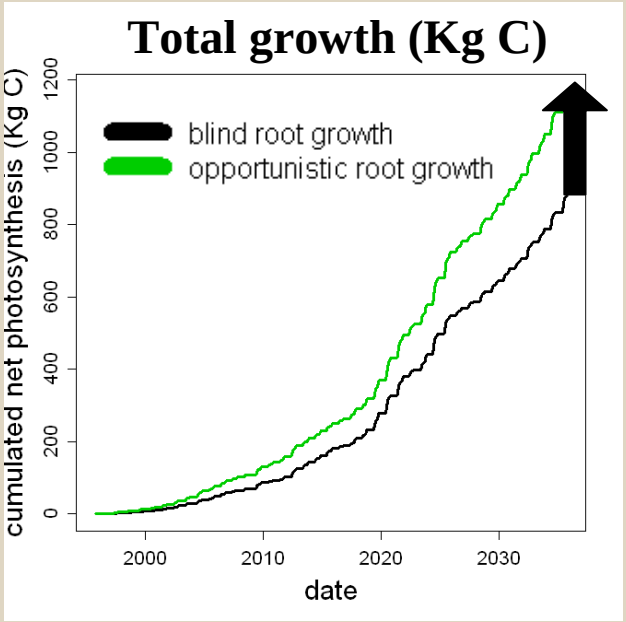


III. 3 Results: Opportunistic root system : effect on fine root distribution



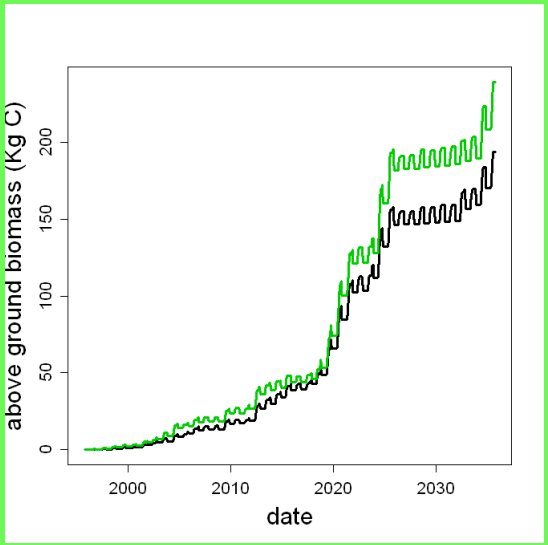


III. 3 Results: Opportunistic root system; effect on tree growth



+ 33% explained by :

- total PAR intercepted : +12 %
- light use efficiency : +19 %

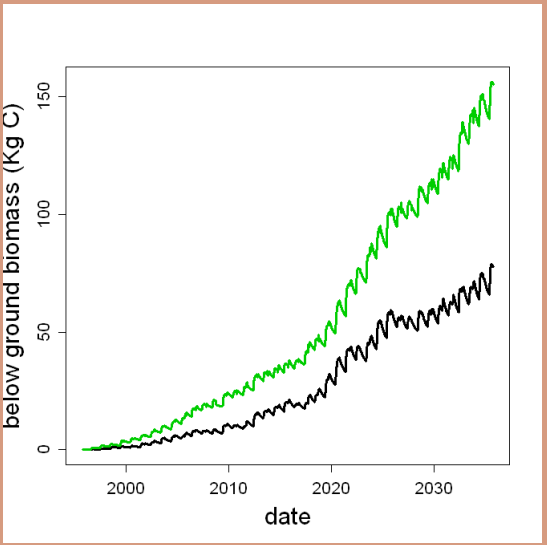


Above ground biomass

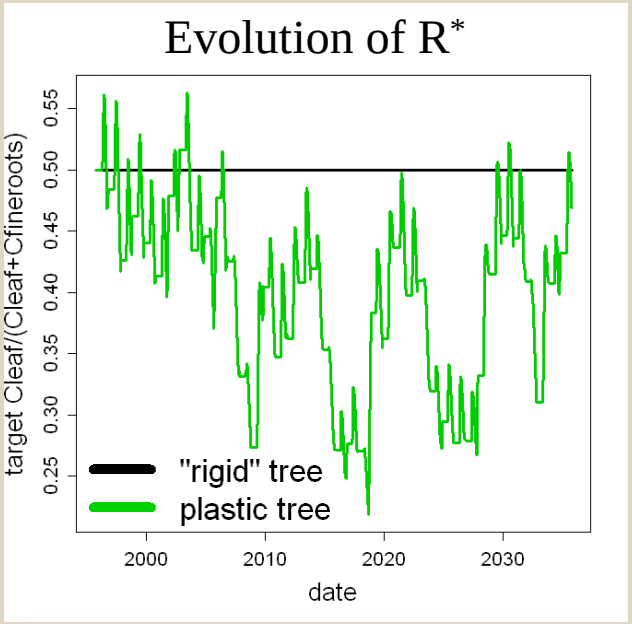
+23 %

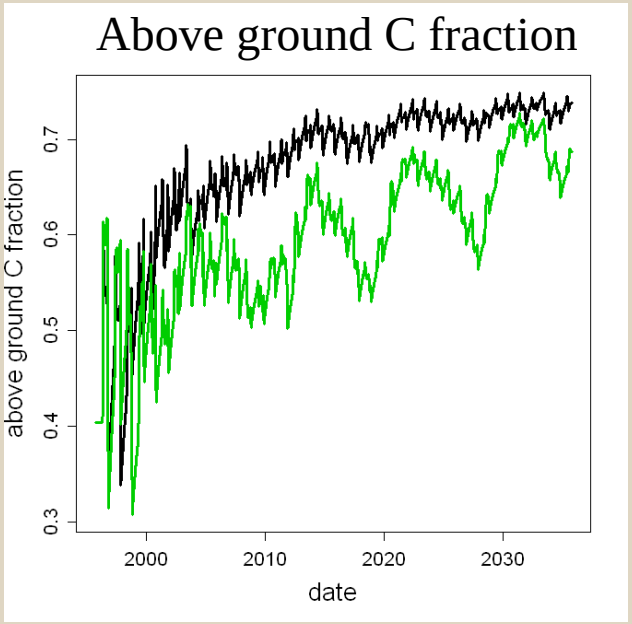
Below ground biomass

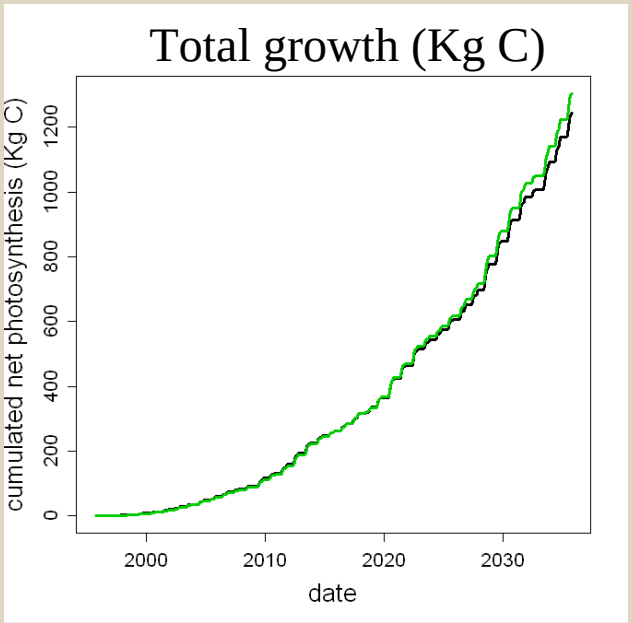
+100 %



III. 3 Results: Plasticity of carbon allocation; effect on tree growth







+ 5% explained by :
  - total PAR intercepted : -11 %
  - light use efficiency : +17 %

IV. Conclusions

IV. Conclusions

- Our models were able to simulate observed patterns of plasticity
  - Crown plasticity: reconstruction of the observed difference between N-S and E-W orientation;
  - Roots plasticity: higher fine root density below the layers exploited by crop roots

- They were sensitive to the values of parameters governing plastic responses
  - These parameters are difficult to parameterise because they have no simple biological meaning

- Cf communication of Dupraz et al., session 23, Thursday morning
- To be continued…

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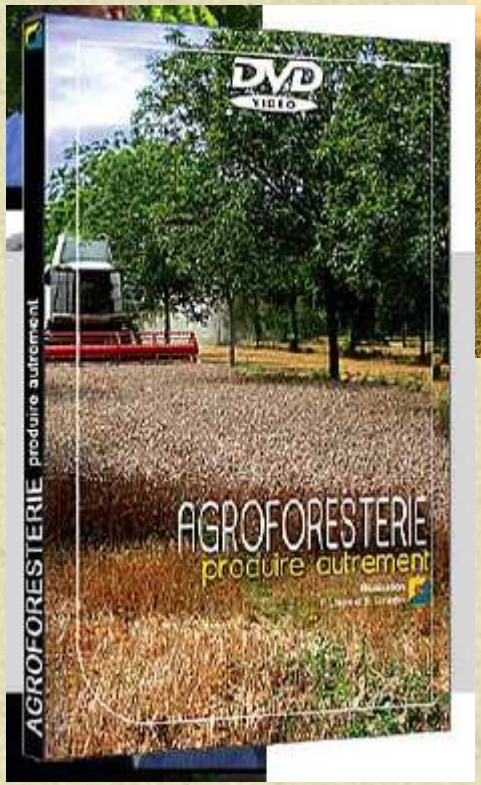


II. 1 The model: STReTCH

Shape transformation response of trees in crowded habitats

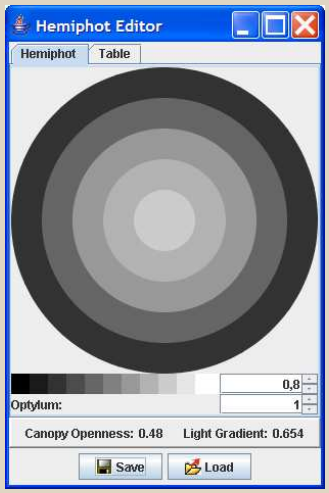
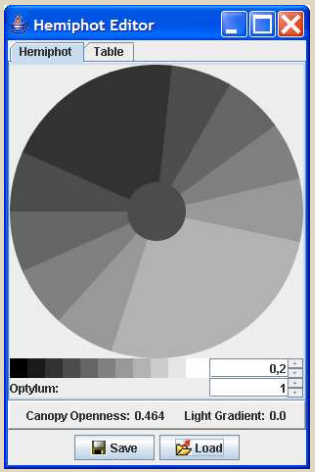
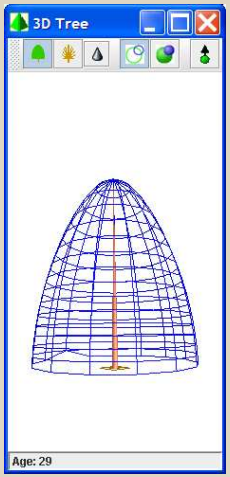
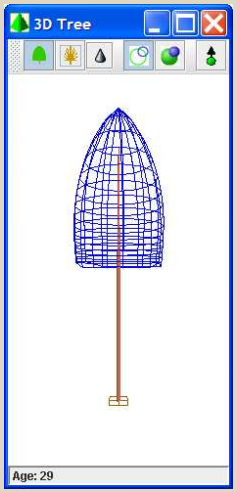


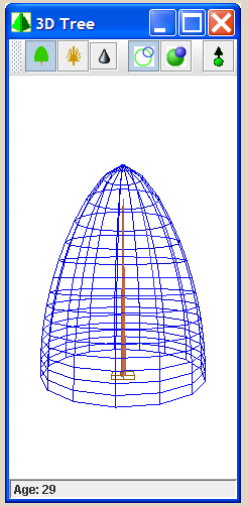
Illustration of crown deformation

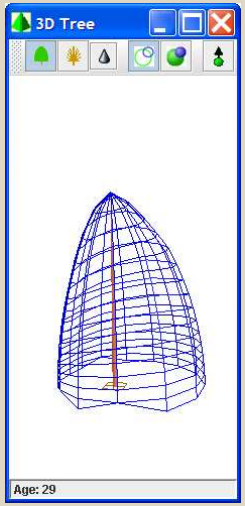






a fixed vertical light gradient





a fixed lateral anisotropic gradient